



# LYCAN: The LYman Continuum ANalysis project

Christian Binggeli  
Uppsala University

Erik Zackrisson, Kristian Finlator, Nickolay Gnedin, Akio k.  
Inoue, Hannes Jensen, Sadegh Khochfar, Genoveva Micheva, Jan-  
Pieter Paardekooper, Ikkoh Shimizu, Sambit Giri, Kristiaan  
Pelckmans, Kristina Ausmees, Ulrika Lundholm



UPPSALA  
UNIVERSITET

# Take-home message

- **JWST/NIRSpec should be able to find galaxies with high amounts of LyC leakage at  $z \sim 6-9$ .**
- **This project can piggy back on other NIRSpec surveys and the ERS program.**

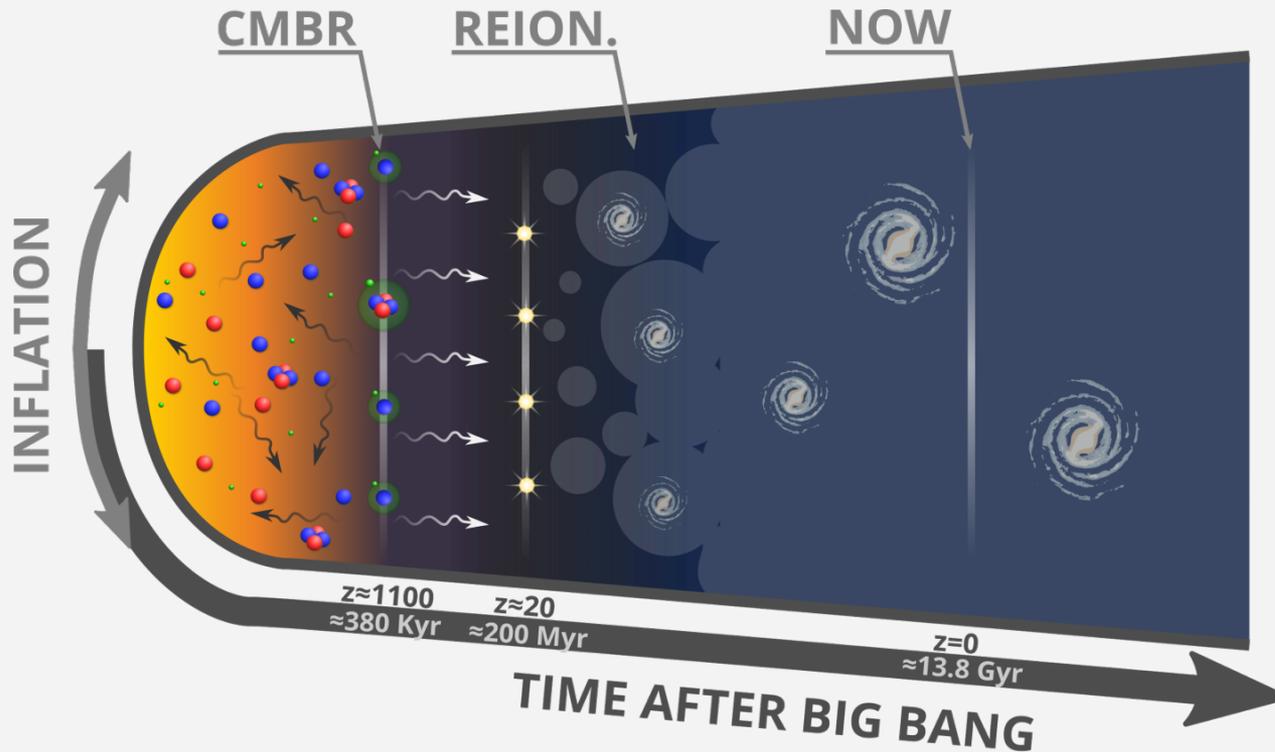
Zackrisson et al. 2013, ApJ, 777, 39

Jensen et al. 2016, ApJ, 827, 5

Zackrisson et al. 2017 ApJ, 836, 78

# The cosmic reionization

How and when?

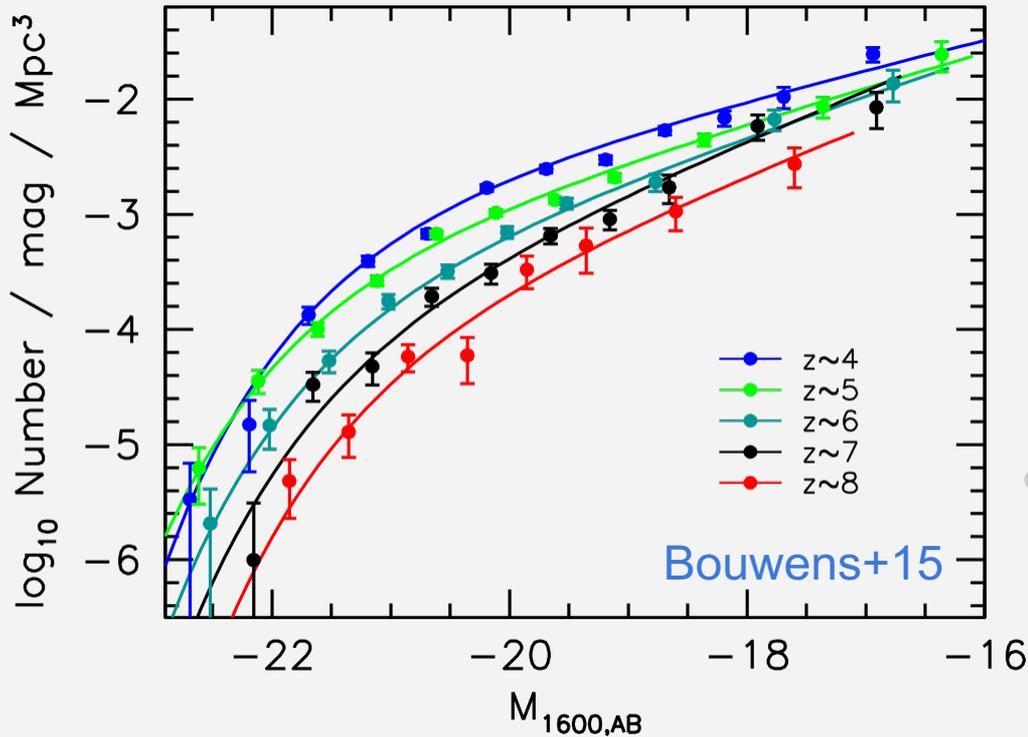


We know roughly when reionization happened (CMBR, quasars,  $\text{Ly}\alpha$ , etc.), but not how.

To reionize the universe we need a source of ionizing radiation. We suspect star forming galaxies.

# Cosmic reionization

Number of galaxies from the UV luminosity function



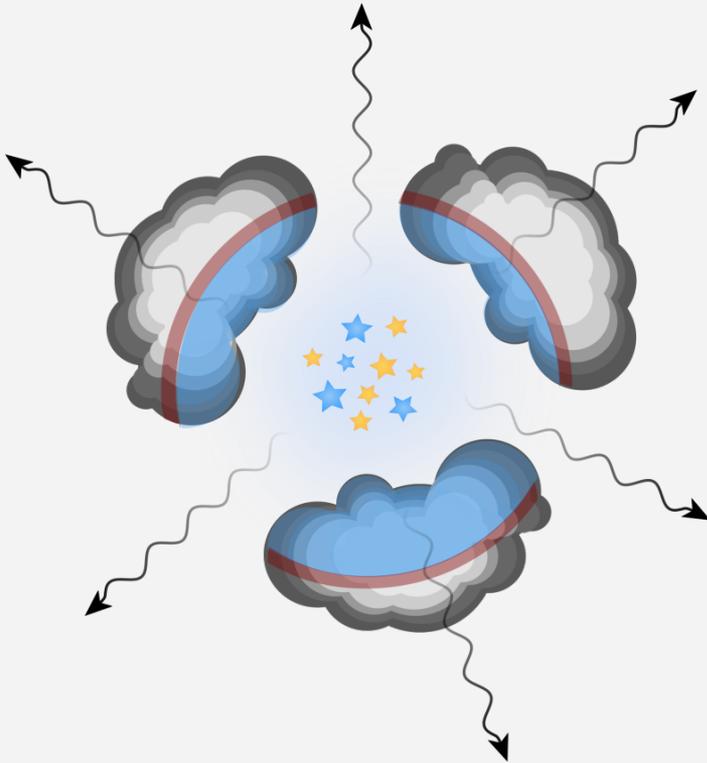
## Requirements for galaxy driven reionization:

- Star forming galaxies have to be numerous at EoR
- They have to allow the ionizing radiation to escape into the IGM

**Probe UV luminosity function!**

# Cosmic reionization

The escape fraction of EoR galaxies



## Requirements for galaxy driven reionization:

- Star forming galaxies have to be numerous at EoR
- They have to allow the ionizing radiation to escape into the IGM

**Impossible to directly measure at  $z > 5$**

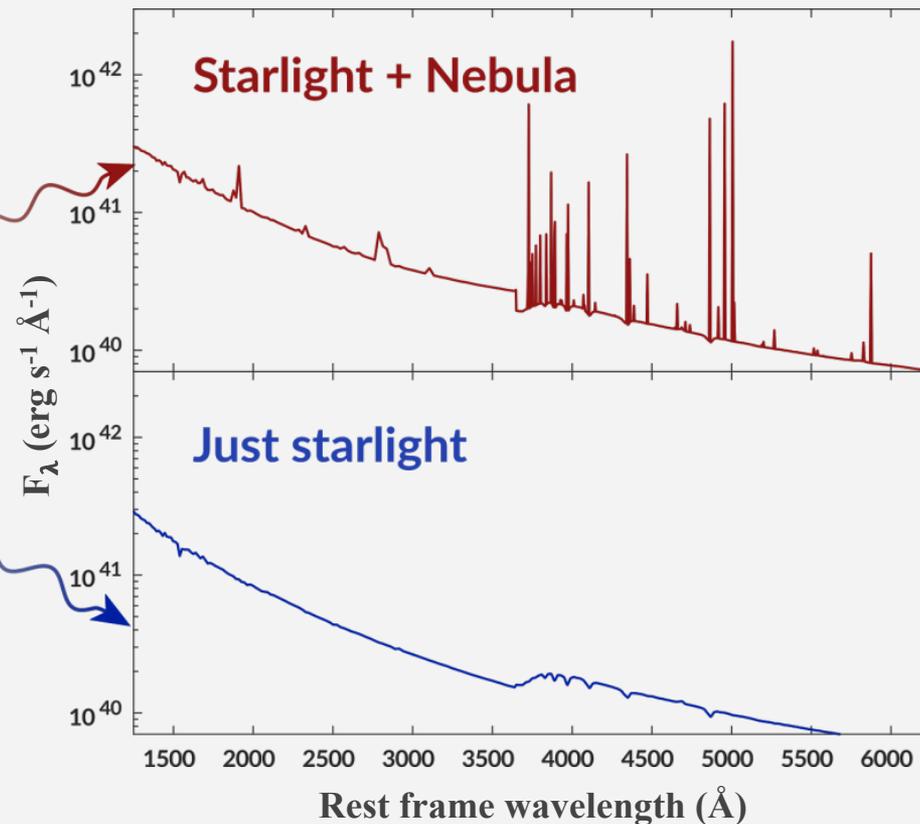
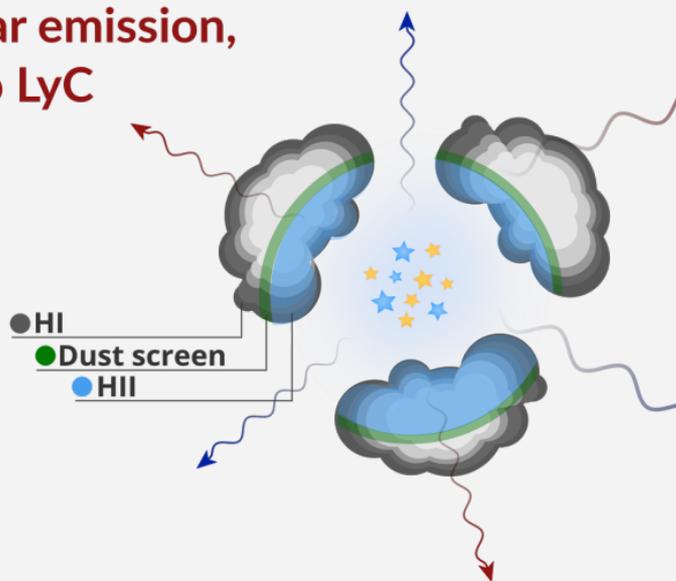
We have to determine it indirectly!

# LyC leakage

## Indirect determination

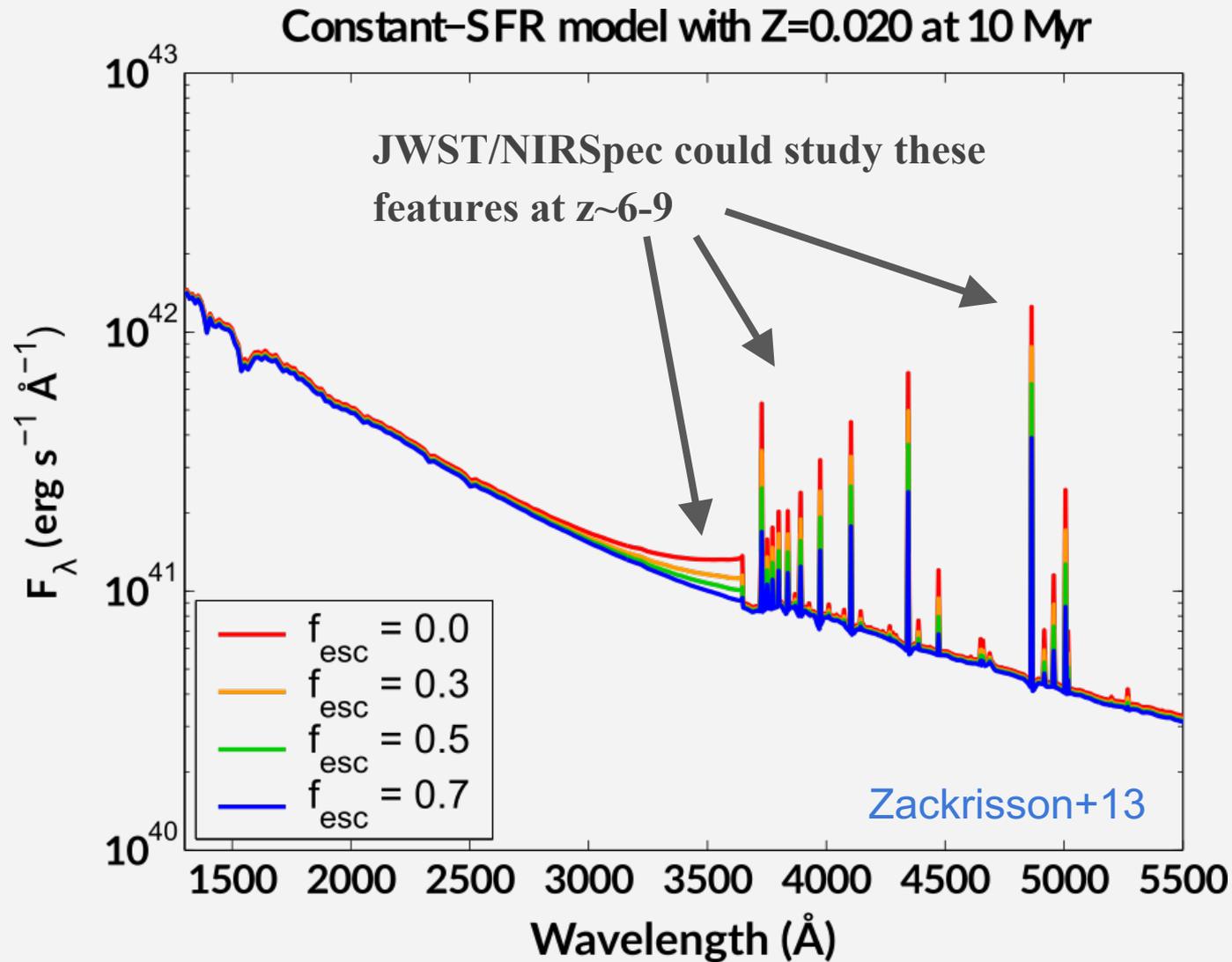
Attenuated starlight with nebular emission, but no LyC

Direct starlight with LyC



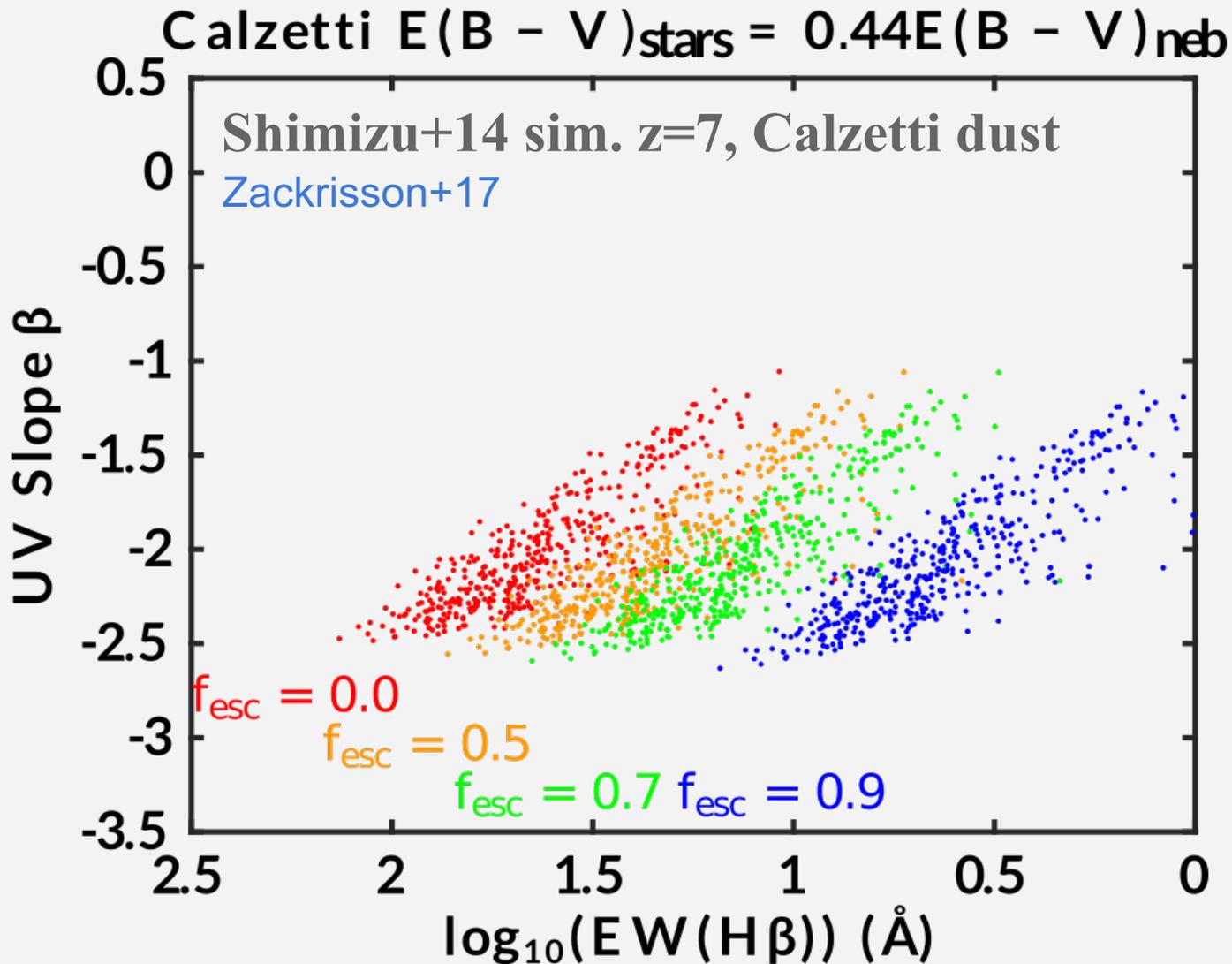
# LyC leakage

Spectral features linked to escape fraction



# Estimating escape fraction: results

A simple diagnostic using only 2 spectral features



# Estimating escape fraction

Simulated galaxies

Cosmological simulations + SED models

(stars, gas) + dust + JWST/NIRSpec

resolution & noise.

→ **Mock JWST spectra with LyC leakage**

**Simulation suites:**

CROC (Gnedin 2014)

FiBY (Paardekooper et al. 2015)

Finlator et al. (2013)

Shimizu et al. (2014) and (2016) - ongoing work

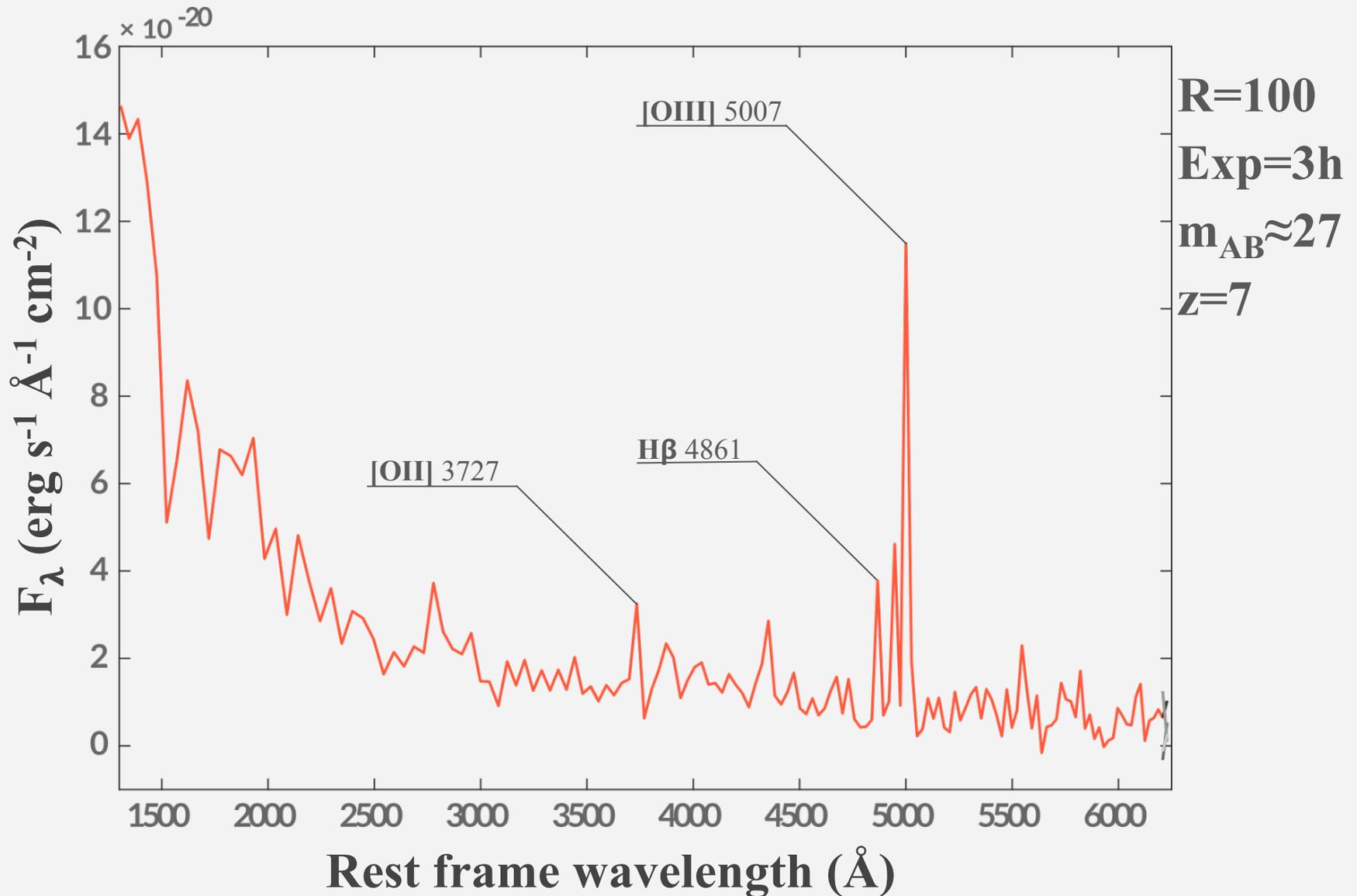
EAGLE, McAlpine (2015) - ongoing work



SEDs publicly available at: <http://www.astro.uu.se/~ez/lycan/lycan>

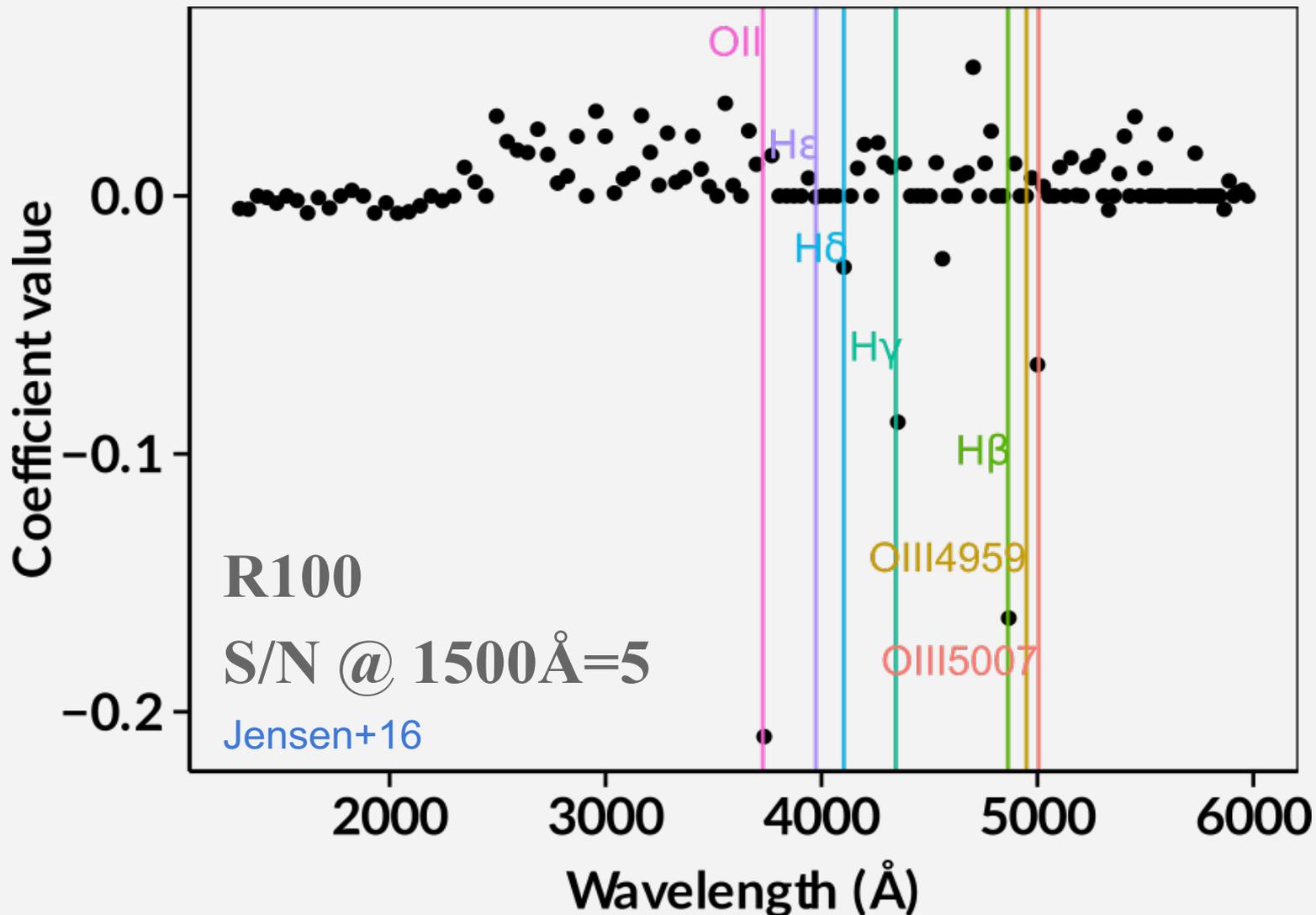
# Estimating escape fraction: results

Mock spectrum of reionization epoch galaxy



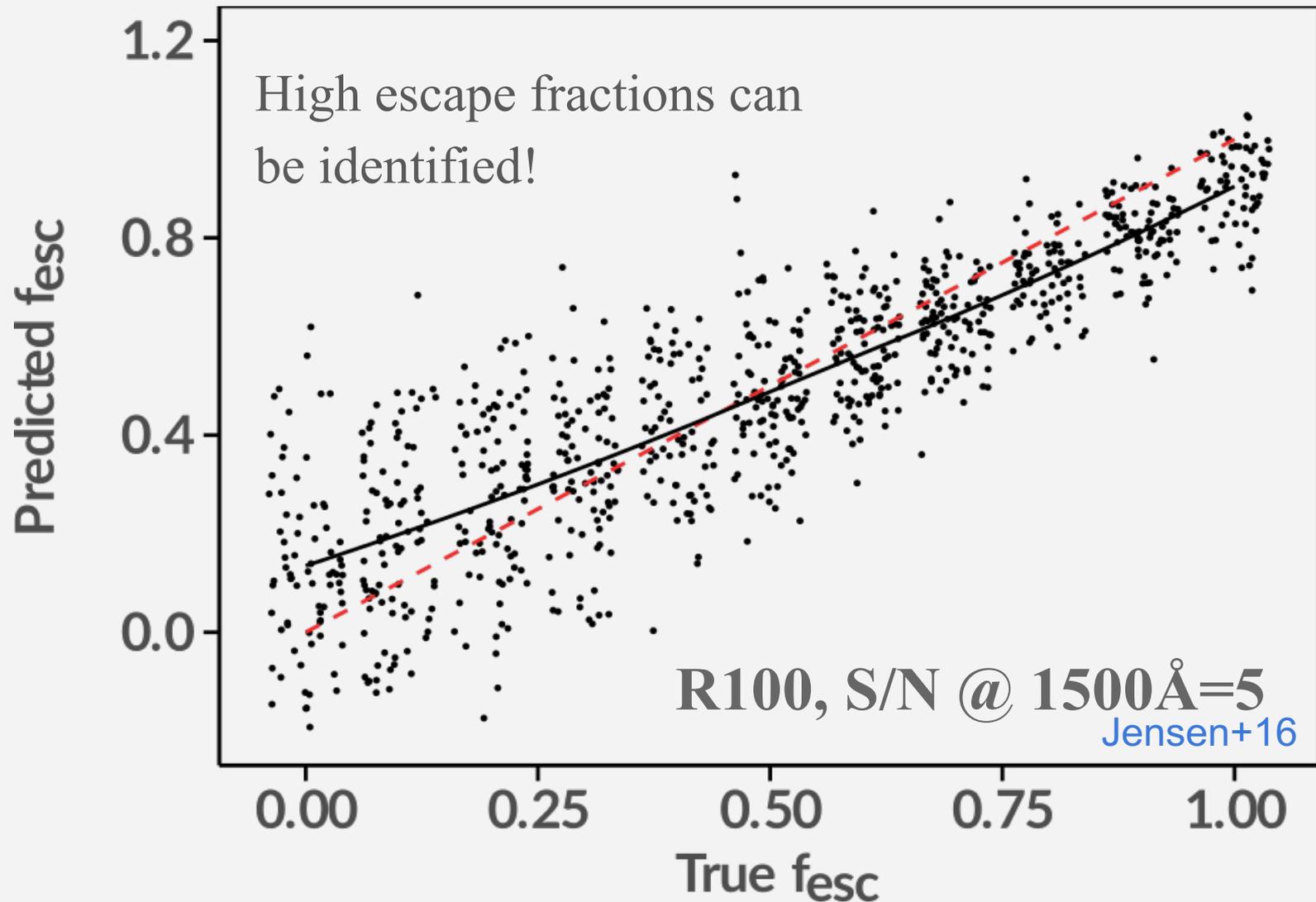
# Estimating escape fraction: results

Features linked to escape fraction according to LASSO



# Estimating escape fraction: results

Using more features with machine learning



# Estimating escape fraction: results

Limitations of the method

## What you can and cannot (currently) do:

- You **can** identify galaxies with extreme leakage
- You **cannot** get reliable estimates of  $f_{\text{esc}}$  of galaxies with  $f_{\text{esc}} < 0.3$

# Summary & Future things

- Leakage of LyC radiation from star forming galaxies is crucial for galaxy driven reionization
- JWST/NIRSpec allows us to identify galaxies with high LyC leakage
- Our SEDs are publicly available!  
<http://www.astro.uu.se/~ez/lycan/lycan>
- Ongoing: Estimating the escape fractions of galaxies in the frontier fields (see talk by S. Giri)
- Ongoing and future: Synergies between the JWST and the SKA

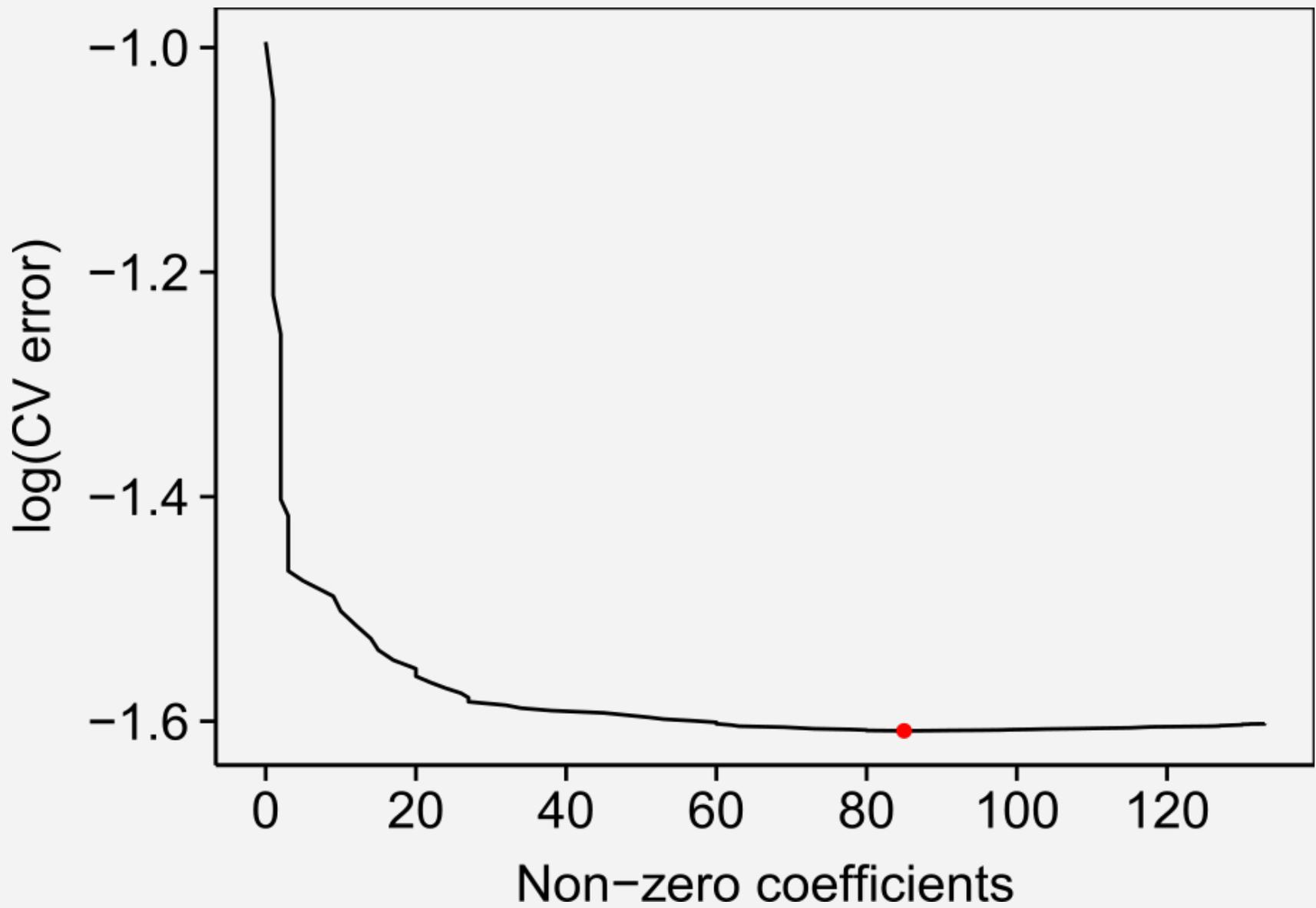
**Thank you for listening**

# Ongoing and future work

- **Get a better handle on leakage mechanisms: Ionization-bounded vs density-bounded leakage**

---
- **Constraints on SFH effects, what happens if there are quenched galaxies in the early universe?**

---
- **Estimating the escape fractions of galaxies in the frontier fields (see talk by S. Giri)**



# Estimating escape fraction: results

A simple diagnostic using only 2 spectral features

